Neuro-fuzzy model of reliability evaluation of the sales planning

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Abstract — **The article is devoted to the application of the theory of fuzzy sets and neural networks to evaluate the degree of reliability in purchases and sales planning. Moreover, this article describes the model of separation of reliability levels depending on the sales stability, correctness of the selected interval and frequency of planning. The stability of sales is a key indicator allowing manager to decide about carrying out planning "by hand". Automatic planning of purchases for future periods is possible if the sales for the prior period are stable. The result is a description of the configuration of a neuro-fuzzy network, in order to make a decision about the level of planning reliability. During this study the neuro-fuzzy network is trained on real sales data from a large trade and purchasing enterprise.**

Keywords—sales management, purchase management, reliability planning, neuro-fuzzy, neuro-fuzzy model

I. Introduction

For the effective operation of a trade and purchasing enterprise under the conditions of fierce competition it is necessary to pay due attention to the planning of purchase and sales [8, 9]. In order to satisfy demand and not lose customers, it is important to have in-demand goods in stock without overloading storage capacities. The choice of forecasting methodology largely depends on the strategy, type of activity and size of enterprise.

II. Actuality

Most planning techniques involve a retrospective analysis of sales data, that is, collecting data from past periods and extrapolating them. The most common way of forecasting the sales volumes is based on finding the trend for previous periods and taking this value as a reference for necessary purchase. If further planning based on the trend is carried out completely automatically, this can lead not only to overloading the warehouse capacities, but also to a large number of refusals to customers caused by lack of demanded items in the warehouse. On the other hand, manual planning (without automation) with a large volume of nomenclature can lead to an excessive, unnecessary workload on staff.

The key to solving the problem of planning optimization with separating the functions of personnel and information system is to determine the sales stability of a particular nomenclature position. Automatic planning with a high degree of reliability without manager's involvement is possible for those products that have stable sales. The same stock items but with unstable sales, require manual checking and adjustment of the values planned.

III. Formulation of a problem

In articles [2, 3], the authors proposed a methodology that implements a mechanism for expert evaluation of the degree of reliability planning the purchases and sales with color interpretation. This methodology allows to inform manager for which nomenclature items the automated sales planning is reliable, and which ones require "intuitive", that is, "manual" correction of the data received. The described methodology allows to solve the problem of reliability evaluation of planning. But despite this, the usage of it with a large volumes and variety of nomenclature items can lead to a large number of positions in the forecast with the same level of planning reliability. This in turn can lead to the uncertainty in the manager's prioritization for adjusting and validating data and, as a result, will reduce the efficiency of the employee. To optimize the work of a manager, who must clearly understand which nomenclature names require special attention when planning in the first place, it becomes necessary to formalize the concept of "reliable forecast", with separating of different levels of reliability, such as: "reliable", "unreliable" "doubtful", etc. This approach will allow employees to streamline their work by correctly prioritizing data adjustments and validation in the process of forming a sales and purchase plan.

This work is devoted to the study of the possibility of creating an information system for reliability evaluation of procurement and sales planning using the ideas of the theory of fuzzy systems and neural networks with training.

IV. Theoretical base

The articles [2, 3] consider the model of value change of sales volume X in time, which can be expressed by formula

$$X_q = G(q) + \eta(q),$$

where G(q) is a function expressing deterministic rule of evolution of the value X (trend) depending on the time moment with number q;

$\eta(q)$ is a random variable characterizing the deviation of the actual value of the indicator from its trend (hereinafter, we assume that $\eta(q)$ is an uncorrelated random value with zero mathematical expectation).

Estimates of the average value and standard deviation of the X indicator can be expressed as follows:

$$\hat{p}_0 = \hat{G}(q);\ \hat{\sigma}_p^2 = \frac{\sum_{i=0}^{J}(X_i - \hat{p}_0)^2}{J-1},$$

where J is the number of points in time involved in the assessment.

The reliability of the extrapolation of the indicator X is estimated by a discrete set of values based on the truth of three conditions:

1.The X_i values lie close to their average value, that is, for all i:

$$X_i - \hat{p}_0 < k\hat{\sigma}, \qquad (1)$$

where k is a given parameter of the confidence interval width.

2.Extrapolated X_i values are not equal to 0 with a high degree of reliability:

$$\hat{p}_0 - k\hat{\sigma} > 0, \qquad (2)$$

3.For all i, that is, among X_i , there are no zero values:

$$X_i > 0. \qquad (3)$$

These given conditions are checked for each nomenclature item. Then, based on a set of condition values, a decision for the reliability of planning is taken.

A discrete evaluation of the reliability level of sales planning allows to draw the manager's attention, first of all, to checking the most unreliable planned values. At the same time, with a wide variety of nomenclature items, there may be too many products with the same level of planning reliability, and this will not allow employee to adequately estimate the situation. In this case, the task of representing the reliability level as a continuous value becomes urgent. Here it is rational to use the ideas underlying the tasks of fuzzy logic systems. A similar approach is implemented and successfully applied in many other fields of activity, not only in economics [5, 1], but in technics as well, for example, in evaluating the danger of vessel traffic [4].

To solve the task set - the transition from discrete to continuous evaluation of reliability, it is advisable to use a neuro-fuzzy network. Three linguistic variables characterizing the sales stability, correctness of the selected interval, and frequency, with the terms "large" and "small" are submitted to the input of this network.

Let $U_1 = \max\left(\frac{x_i - m}{\delta}\right)$ be the estimated value of the stability of sales (1). Let us enter the linguistic variable P_1 "estimation of the value U_1" with the terms "large" and "small" and membership functions of the "complement" type defined on the universal set $U_1 \in [0, 3]$:

$$\mu_{small}(U_1) = 1 - \frac{1}{1+\exp\left(-a_{U_1}(U_1 - c_{U_1})\right)};$$

$$\mu_{large}(U_1) = \frac{1}{1+\exp\left(-a_{U_1}(U_1 - c_{U_1})\right)}.$$

The term "small" corresponds to a situation where the extrapolated values do not go beyond the confidence interval, are close to their average, and this means that sales can be considered as stable. The term "big" suggests that sales are unstable and may be seasonal.

Let $U_2 = {}^{m}/_{\delta}$ be estimated correctness of the selected interval (2). Let us enter the linguistic variable P_2 "estimation of the value of U_2" with the terms "large" and "small" and membership functions of the "complement" type, defined on the universal set $U_2 \in [0.3]$:

$$\lambda_{small}(U_2) = 1 - \frac{1}{1+\exp\left(-a_{U_2}(U_2 - c_{U_2})\right)};$$

$$\lambda_{large}(U_2) = \frac{1}{1+\exp\left(-a_{U_2}(U_2 - c_{U_2})\right)}.$$

In this case, the term "small" indicates that there are not enough data for planning, the term "large" indicates that during the planning period, sales will take place for the item selected.

Let $U_3 = \frac{\min(x_i)}{m}$ be the estimated correctness of the selected frequency (3). Let us enter the linguistic variable P_3 "estimation of the value of U_3" with the terms "large" and "small", and membership functions of the "complement" type, defined on the universal set $U_3 \in [0, 2]$:

$$\nu_{small}(U_3) = 1 - \frac{1}{1+\exp\left(-a_{U_3}(U_3 - c_{U_3})\right)},$$

$$\nu_{large}(U_3) = \frac{1}{1+\exp\left(-a_{U_3}(U_3 - c_{U_3})\right)}.$$

The term "small" means that the frequency of data analysis was chosen incorrectly. In particular, if a certain item is sold only once a month, then it makes no sense to take the period for calculations and forecasting equal to a week. The term "large" corresponds to the correctly chosen planning frequency.

The values P_1, P_2 and P_3 (input) are processed by the neuro-fuzzy network shown in Fig. 1, and at the output of the network a numerical value $u \in [0, 3]$ is formed - the degree of reliability of planning purchases and sales; the value $u = 0$ corresponds to the lowest degree of reliability, $u = 3$ – to the highest. The network consists of five layers [6] (Fig. 1).

In the nodes of the first layer μ_1, μ_2, λ_1, λ_2, ν_1, ν_2, the values of the membership function are calculated, they are μ_{small}, μ_{large}, λ_{small}, λ_{large}, ν_{small}, ν_{large} correspondingly. Nodes P of the second layer (8 nodes in total) correspond to the terms of 8 possible fuzzy rules, combining all possible values of P_1, P_2 and P_3 ("Table 1").

Fig. 1. Scheme of a neuro-fuzzy network, determining the degree of reliability of planning purchases and sales

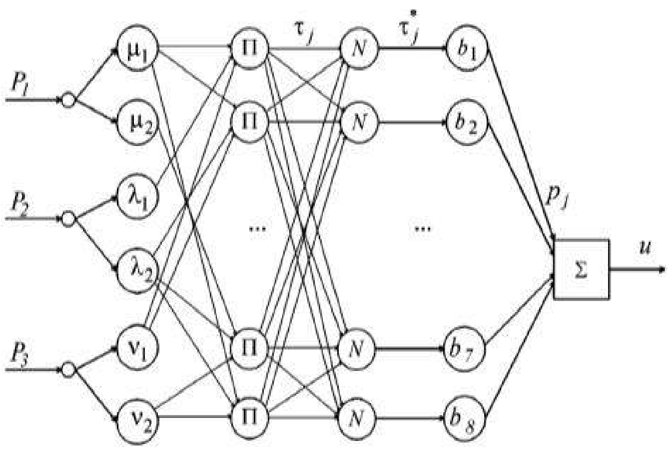

TABLE I. FUZZY RULE SYSTEM

	P_1	P_2	P_3	u
1	small	small	small	0
2	small	big	small	0

3	big	small	small	0
4	big	big	small	0
5	big	small	big	1
6	small	small	big	2
7	big	big	big	2
8	small	big	big	3

Each node of the second layer is connected to those nodes of the first layer that form messages of the corresponding rule. The output of each second layer node is the degree of fulfilment of the jth rule τ_j, which is calculated as product of the input signals. Nodes N of the third layer calculate the relative degree of fulfilment of each fuzzy rule by formula

$$\tau_j = \frac{\tau_j}{\sum_{k=1}^{8} \tau_k}$$

Nodes b_1, b_2, ..., b_8 of the fourth layer form the conclusions of fuzzy rules; in fact, b_j are the values of the network output when only the jth rule is definitely fulfilled. Each node is connected to one node of the third layer and calculates the contribution of one fuzzy rule to the network output using the formula $p_j = b_j\tau_j$.

A single node of the fifth layer aggregates the result obtained according to different rules, summing the contributions of all rules

$$u = \sum_{k=1}^{8} p_j$$

Neuro-fuzzy network training (Fig. 1) consists in setting the parameters of membership functions $a_{U_1}, c_{U_1}, a_{U_2}, c_{U_2}, a_{U_3}, c_{U_3}$ and coefficients b_1, b_2, ..., b_8 of the fourth layer nodes. Training can be carried out using different methods. In this case, training was carried using a training sample with expert formation of fuzzy rules conclusions. The coefficients b_j were set by an expert, and the parameters of the membership functions were determined by tuning the system on the training sample.

The training sample is formed as follows. The solution of the problem is simulated with the estimation of conditions (1), (2) and (3) for various nomenclature items. If the forecast is "unreliable", that is, u = 0, manual planning is required; if u = 1, then the forecast is "doubtful" and the planned values must be checked. If the forecast has a minimum error, that is, it is “convincing”, then u = 2, and checking the values is at the manager’s discretion and is optional. If the forecast is “reliable”, u = 3, then plan of purchases does not require verification. With accumulation sales data of different goods for different periods, a general training sample "input-output" is formed. The network is trained on base of this sample (Fig. 1), with the use of well-known training methods for this type of networks [6, 7].

V. Practical Significance, Proposals and Results of Experimental Studies

Numerical modeling of the problem under consideration was carried out at the MATLAB system [7]. The training sample was formed on real sales data of a large trade and purchasing enterprise selling auto parts for the period of 12 months with a 2 months frequency for 700 nomenclature items.

The following values of the membership functions parameters μ_{small} (P_1) were set: μ_{large} (P_1), λ_{small} (P_2), λ_{large} (P_2), ν_{small} (P_3), ν_{large} (P_3) were set: $a_{U_1} = 7.799$; $c_{U_1} = 1.5$; $a_{U_2} = 7.799$; $c_{U_2} = 1.5$; $a_{U_3} = 20.8$; $c_{U_3} = 0.3$.

In this case, the initial parameters of the membership functions were set by an expert, then the system was trained and tuned.

The training of the system was carried out with the following values of the parameters b_j, corresponding to 8 possible fuzzy rules: $b_1, b_2, b_3, b_4 = 0$; $b_5 = 1$; $b_6, b_7 = 2$; $b_8 = 3$. The error after configuring the network was 0.111.

As a result, after tuning and training the hybrid neural fuzzy network, the values of the continuous estimation of the planning reliability were obtained (“Table 2”).

TABLE II. DISCRETE AND CONTINUOUS ESTIMATES OF THE DEGREE OF PLANNING CONFIDENCE

Number of position	Sales volume in the period (pieces)						Discrete assessment	Continuous assessment
	1 period	2 period	3 period	4 period	5 period	6 period		
1	7	6	52	49	52	35	1	0.8739
2	6	63	109	122	110	72	1	0.3357
3	3	8	24	2	17	6	1	0.9965
4	200	556	1055	1307	633	64	1	1.0113
5	6	63	109	122	110	72	0	0.3357
6	ten	31	50	16	31	ten	2	2.2962
7	5	16	30	40	9	12	2	1.9356
8	131	210	400	191	144	100	2	2.3820
9	12	24	30	46	18	10	3	2.6765
10	18	24	80	60	62	22	3	2.8940

Comparing the discrete and continuous values of the estimate, we can see that for many nomenclature items with the same discrete estimation, the continuous value differs on average within up to 0.5 (Fig. 2), and this will allow an automated system based on this network to automatically rank the forecast within one level of confidence.

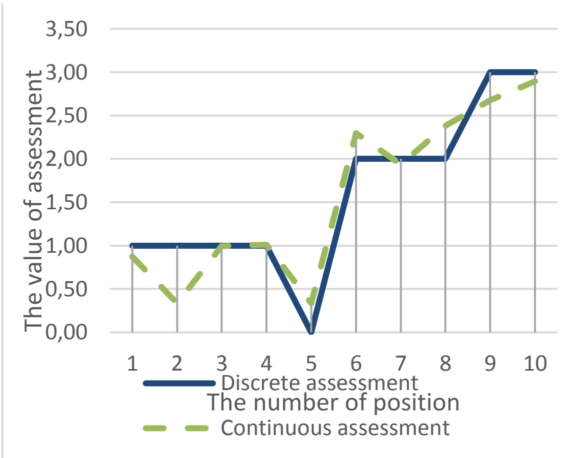

Fig. 2. Discrete and continuous value of the assessment of the degree of confidence

VI CONCLUSION

During this study the neuro-fuzzy network is trained on real sales data from a large trade and purchasing enterprise. The simulation results obtained confirm the expected effect of separating the reliability levels depending on sales stability, correctness of the selected interval, and the frequency planning. The proposed model of neuro-fuzzy system can be successfully applied in practice to assess the degree of reliability of purchases and sales planning.

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